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# STOPPAGE OF FLOW IN A WATER MAIN BY ANCHOR ICE.

By JAMES B. FRANCIS, Past President Am. Soc. C. E.

READ DECEMBER 15TH, 1886.

## WITH DISCUSSION.

Carleton, a district of St. John, New Brunswick, is supplied with water from Spruce Lake by means of a cement lined sheet-iron pipe 12 inches in diameter and about seven miles long.

This pipe discharges into a distributing reservoir in the outskirts of the town, which has a depth of water, when full, of 18 feet, and a capacity of about one and three-fourth million imperial gallons. This pipe was discharging to its full capacity, or at the rate of about three hundred thousand gallons in twenty-four hours, with the water in the reservoir drawn down about ten feet, leaving a depth of water and ice of about eight feet.

A plan and section of the reservoir, showing also the inlet and outlet pipes, is given on Plate XVII.

On the evening of December 8th, 1882, the supply of water to the district suddenly ceased, and so continued for a short time until other

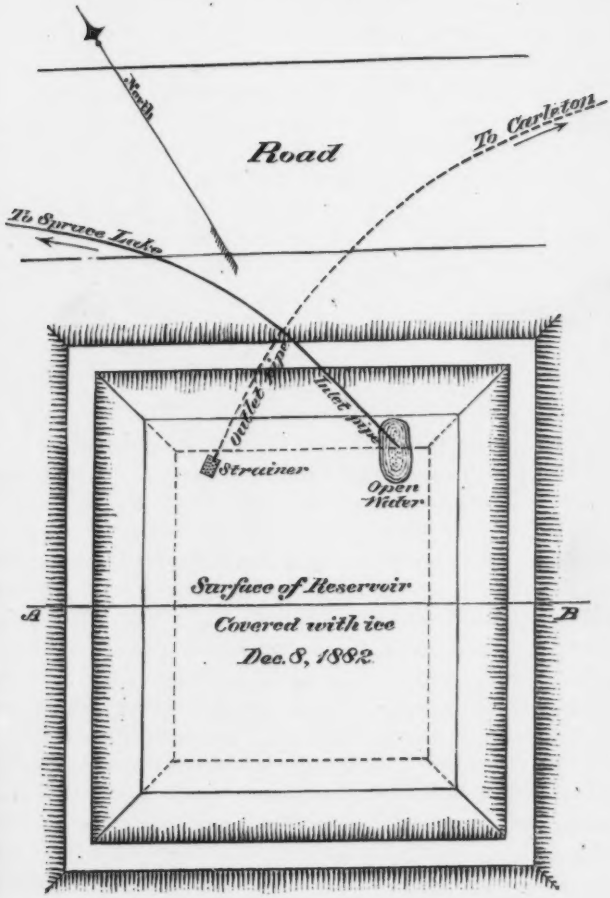
connections were opened. On the following morning a hole was cut in the ice, which was about six inches thick, immediately over the outlet pipe, where a mass of ice was found, which is described as a kind of slush or minute particles of congealed water; on prying upon it, it floated up, and the bottom of it was exactly the shape of the strainer of the outlet pipe, showing that it rested upon it and completely closed up the outlet. The strainer is a copper rose perforated with holes about one-fourth of an inch in diameter, the marks of which appeared upon the ice. The whole column when taken out, or as much of it as would hold together, was about the size of a barrel, and was composed of minute particles of ice, all standing on end, firmly adhering to each other. On removing this ice the water commenced to flow to the town as usual.

The temperature of the air had fallen suddenly from 43 degrees above zero at 8 P.M. of the 7th to 10 degrees above at 8 A.M. of the 8th, with a mean for the day of 12.3 degrees. The sky was clear and had been so for the greater part of the day, and the wind was blowing a strong gusty breeze (twenty to thirty miles an hour) from the north-west.

Spruce Lake was entirely frozen over, and the reservoir was covered with ice, except over the inlet pipe, where there was an area of two or three hundred square feet clear of ice.

The temperature of the water in Spruce Lake, reservoir or mains, was not observed at the time, but from observations at other times it is stated that the usual winter temperature of water drawn from the mains is about 35 degrees.

The City of St. John (East) is supplied with water in a similar manner to Carleton (or St. John West), but from Little River Reservoir, by means of three mains, one of 12 inches and two of 24 inches diameter, and about five miles long. The reservoir has an area of 37.5 acres, and was completely frozen over from November 27th, 1882, to May 5th, 1883, and from December 1st, 1883, to April 22d, 1884. Records are kept of the temperatures of the air and water at the gate-house at Little River Reservoir and as drawn from the mains in the city, and are given in the annual reports of the Superintendent of the Water-works. I find in these reports the data for the temperatures in the following table, which are the means for the respective months in the years 1882, 1883 and 1884:




SECTION THROUGH AB.

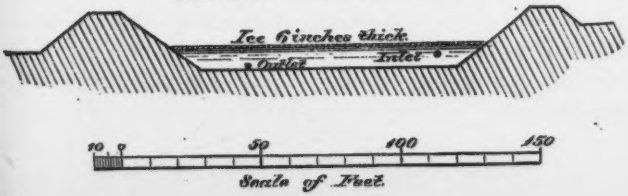



PLATE XVII.

| | December. | January. | February. | March. |
|---|---|---|---|---|
| | Degrees. | Degrees. | Degrees. | Degrees. |
| Mean temperature of the water in the gate-house 2 feet below the surface ..... | 34.34 | 34.10 | 33.90 | 33.84 |
| Mean temperature of the water as drawn from the mains in the city . | 36.28 | 35.28 | 34.47 | 34.13 |
| Difference..... | 1 94 | 1.18 | 0.57 | 0.29 |
| Mean temperature of the air for the three years. | 22.79 | 15.80 | 20.42 | 28.92 |
| Mean temperature of the air for twenty-four years, 1861 to 1884.... | 22.02 | 18.13 | 21.11 | 27.35 |

In the absence of similar observations for the Carleton Water-works, the localities and arrangements being so nearly alike, I think we may safely infer from the above table that the temperature of the water entering the Carleton Reservoir December 8th, 1882, when the stoppage occurred, was not below 36 degrees Fahr., or 4 degrees above the freezing point.

The discharge of the inlet pipe being 300 000 imperial gallons in twenty-four hours, the mean velocity of the water entering the reservoir was about 0.71 feet per second, and the center of the pipe was about 3.5 feet below the surface of the water. This must have produced an agitation in the part of the reservoir near the inlet pipe in the form of eddies in various directions, some of them extending to the surface, and the temperature of the entering water being above the freezing point, the result was the open water of two or three hundred square feet over and near the inlet pipe.

Anchor ice, according to my observation, is originally formed on the surface of water which is agitated, either by a current or the wind; it is formed in minute particles or needles, which, as they differ little from the specific gravity of the water, are carried by currents or eddies in any direction, and when they come in contact, either with one another or with other substances of the same temperature, freeze together, or, as described by Faraday, who appears to have been the first to observe the phenomenon, but in larger masses of ice, *regelate*. According to this

theory, the ice which closed the strainer formed on the open water over the inlet pipe, was carried under the ice by eddies and currents, and continued in motion until it reached the strainer.

The quantity of water in the reservoir when drawn down as above stated, was about five hundred and sixty thousand imperial gallons, and as the daily consumption of water was about three hundred thousand gallons, the entire contents must have been changed, on the average, every 44.8 hours. The mean temperature of the day immediately preceding the stoppage having been 12.3 degrees, the mean temperature of the water in the reservoir must have been reduced somewhat, but to what extent I have no means of estimating. The water in immediate contact with the ice would of course be reduced to 32 degrees, and the ice would be increasing in thickness. The great mass of the water, not being near the influent or effluent pipes, would be very quiet. The water below the stratum in contact with the surface ice would remain at the temperature at which it entered the reservoir, which we find must have been near 36 degrees, unless cooled from the surface; this could take place only to a very small extent, except by means of a vertical circulation in the mass of water, but as the specific gravity of water at the temperature of 32 degrees is less than at the temperature of 36 degrees, or at any temperature between that temperature and 32 degrees, there could be no such tendency. From these considerations I infer that the temperature of the great mass of the water in the reservoir did not get reduced to the freezing point, and that the particles of ice should not thaw, they must have floated very near the surface ice, and so continued until they reached a point over the strainer on the outlet pipe, arriving there with the water from all directions, and accumulating in a mass, which gradually extended downwards until it reached the strainer. The constitution of the mass of ice which was found on the strainer, as described above, does not appear to be inconsistent with this explanation of its mode of formation.

The reservoir has been in use since its construction in 1874, and although it has frequently been as low in as cold weather, this has been the only occasion when the strainer has been obstructed by ice. What the peculiar conditions were to cause the trouble at this time, and not at others, do not appear to be known, but I think it probable that there was much less open water, if any, on the other occasions.

The information on which this paper is based was communicated to

the writer by Mr. George F. Harding, Chairman of the Board of Water Commissioners for Carleton, and Mr. Gilbert Murdoch, M. Am. Soc. C. E., Superintendent of the Water-works and Sewerage of St. John, N. B.

## DISCUSSION.

CHARLES B. BRUSH, M. Am. Soc. C. E.—I had an experience very similar to that just described on the 2d of January, 1885. The circumstances were almost identical. There was a rapid fall of temperature during that day, from 27 degrees to 11 degrees Fahr. At 20 o'clock needle ice appeared in the reservoir of the Hackensack Water Company, reorganized, at Weehawken, N. J. It first appeared on the surface, and was then drawn down into the wet well of the gate-house through the outlet pipe of the reservoir. The capacity of the reservoir is 15 000 000 gallons, and on the above date the surface of the water was 10 feet above the bottom of the 20-inch outlet. The water was flowing into the reservoir at the rate of about three feet per second, and out at about three and one-half feet per second. The needle ice, on reaching the wet well of the reservoir, commenced immediately to form a thin coating against the screens, thus effectually shutting off the flow of water through them in a very short time. We immediately opened the by-pass, and set men at work with long poles breaking the ice on the screens, and stirring it up in the well. The whole force of the current in the by-pass was then thrown directly on the reverse side of the screens, and after working a couple of hours the trouble ceased. The needle ice was simply driven back into the reservoir and disappeared.

B. S. CHURCH, M. Am. Soc. C. E.—I will mention an experience with anchor ice on a somewhat larger scale which occurred at the entrance of the conduit which supplies water to the City of New York. On the 29th of December, 1872, I received a notice (as engineer in charge of the Croton Aqueduct) from one of my keepers, that the depth of water in the conduit at Sing Sing was rapidly decreasing. Suspecting the cause, I drove at once to Croton Dam and found anchor ice forming in Croton Lake around the mouth of and choking the flow of water in the aqueduct.

The usual depth of seven feet was reduced to five feet and finally to four, by 10.30 A. M.

The thermometer at 7 A.M. stood at 0 degrees Fahr. and at 2 P.M. at + 25 degrees Fahr. in the open air.

The water in the aqueduct 400 feet from its mouth, and from where anchor ice had formed, was at a temperature of + 33½ degrees Fahr.

The mouth of the aqueduct was of the horse-shoe form, 7½ feet wide and 10 feet 8 inches high in the clear. The anchor ice took the form of

a dome twelve or thirteen feet in diameter resting against the vertical masonry face of the aqueduct entrance, and three or four feet below the surface at the upper end of its vertical diameter.

A hot-water pipe-coil and small boiler used for another purpose were fortunately on hand and available. This coil was lowered into the body of the mass of spongy ice and heat applied. Then by the aid of poles and planks the ice was forced through the conduit by five men, after about three hours' labor, which restored again the full flow of water in the aqueduct.

THEODORE COOPER, M. Am. Soc. C. E.—I have no special information to add to the subject of anchor ice. But in this connection it may be interesting to state an anomalous experience in the use of a mixture of glycerine and water in hydraulic machinery exposed to the low temperatures of this climate.

It has been generally accepted that a mixture of about four parts of glycerine to six of water would not freeze when subject to our usual winter temperatures.

It is also an accepted belief that under similar conditions the freezing and melting temperature of liquids is identical.

During the winter of 1885–86 some hydraulic machinery put up by me worked satisfactorily throughout the colder days of the winter, using the above proportions of glycerine and water, without freezing. But in the later part of the winter, during much milder weather, the machinery was disabled by freezing of the pipes. The assistant in charge of the work having been troubled this way several times without discovering the cause, finally tried the solution with a hydrometer and found the top of the liquid in the tank to be nearly pure water. He found on emptying the tank a congealed mass, about the consistency of ice-cream, at the bottom. He stated that though at this time the temperature of the air had been above the freezing point for some days, the temperature of this congealed mass was about zero Fahr.

This appeared so anomalous that I doubted the exactness of his observations, until I found the following statement in regard to the peculiarities of glycerine:

"It is soluble in all parts of water; when exposed to air it gradually absorbs water; cooled *rapidly* it only becomes viscid without congealing even when a temperature of — 40 degrees C. (— 40 degrees Fahr.) is attained; but if kept for some time at a temperature of about 0 degrees C. (32 degrees Fahr.) it gradually forms hard deliquescent crystals which melt only at 22 degrees C. (72 degrees Fahr.). This fact is now used as a means of concentrating and purifying glycerine."

As the discussion on the formation of anchor ice tends to show special conditions of the atmosphere at the time, there may be some special case in the formation of this needle ice not heretofore well recognized.

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(Vol. XVI.—April, 1887.)

# DETERMINATION OF THE SIZE OF SEWERS.

By ROBERT E. MCMATH, M. Am. Soc. C. E.

READ DECEMBER 15TH, 1886.

The quantity of water which may be expected to flow off from a given area, the time or rate of its discharge, and the size of conduit required to convey that quantity at the rate necessary to avoid disastrous flooding, are questions that often arise, and to which answers of some sort must be given by engineers.

Such answers are and must always be largely matters of judgment, based upon an estimate of local conditions and experience in similar cases.

That trained judgment may have the best guide possible under the circumstances, a method of ascertaining the results of experience free from personal bias or the influence of unproved theory is desirable. Such a method in practical form I aim to present in this paper. The method is of general application; the results indicated by the figures given are applicable only to the locality which furnishes the experience. The data I give in detail, in the hope that similar data from other localities may also be published, and so material for a better discussion be made available.

The particular problem whose solution I undertake, is the determination of the size of a storm-water sewer, under the conditions that it shall carry off the water of the great storms of the locality, and that no excess of size and cost be allowed.

The engineer usually has, as positive data, the area to be drained and the gradient of the proposed sewer; he also knows, or should know, approximately the rainfall in inches during storms; the intensity of the rainfall, or the rate of fall during the period of heaviest rain; the duration of such period of great intensity; and the condition of surface as to slopes and permeability.

The importance of all these factors has not always been recognized, and sewers have been built without their consideration. Some of the sewers already built have proven adequate, of which some may be unnecessarily large; others have proven insufficient. If now we can make a comparison of actual sewers and separate out those known to be insufficient, we may arrive at a standard below which we must not go, and, if the experience is extended, we obtain a standard of capacity beyond which we need not go. If this could be done with data drawn from every part of the world, the result might be a safe general rule. But, for the present at least, it is safer for each locality to seek its rule of proportioning sewers from its own experience or from that of places subject to like meteorological and surface conditions.

The City of St. Louis has had a sewer experience of about thirty-five years, during which her sewer system has gradually extended to

| | | |
|---|---|---|
| In 1861 | 31.5 | miles. |
| 1865 | 38.6 | " |
| 1870 | 111.1 | " |
| 1875 | 163.4 | " |
| 1880 | 196.4 | " |
| 1885 | 232.1 | " |
| December, 1886 | 258 | " nearly. |

Of the present mileage about thirty-five miles of sewers are taken into consideration in the following discussion, mostly larger than two feet by three. These include all the known cases of serious flooding.

The proportioning of sewers in St. Louis has from the beginning proceeded on the assumption that one inch of rainfall per hour would reach the sewers, or practically one cubic foot per second from each acre of drainage area.

In the earlier days no close proportioning seems to have been attempted, and in some important cases the area to be ultimately drained was not taken into consideration. Later the proportions have been de-

termined by Weisbach's formula for discharge, assuming that the sewers were to run three-fourths full when discharging one cubic foot per second per acre. The formula, as adapted to computation by Robert Moore, M. Am. Soc. C. E., is $d = \left(\frac{A^2}{10.33\ s}\right)^{\frac{1}{5}}$

in which $d$ = diameter of sewer in feet.

$A$ = area drained in acres.

$s$ = grade of sewer in feet per hundred.

The Weisbach formula gives a discharge for the larger sewers materially less than that by the now generally accepted Kutter formula. The arbitrary assumption of three-fourths full is also an under-estimate of the capacity of the sewers.*

In a paper published in the *Journal of the Association of Engineering Societies*, August, 1886, Robert Moore and Julius Baier show that c in Kutter's formula may, for practical use, be made independent of slope. Using this modification I compute the column headed "Moore *b*," of the following Table No. 1, the column headed "Moore *a*" being computed by the formula given above. Comparison of the formula is made by the ratio $\frac{\text{Moore } a}{\text{Moore } b}$, which ratio it will be noticed is not affected by slope. Using "Moore *a*" as abscissas and "Moore *b*" as ordinates, I have the broken line shown on "Diagram of volume reaching sewers;" but since in the use of Moore *a* in St. Louis the discharge of one cubic foot per acre per second has been assumed, I call the abscissas acres instead of cubic feet, hence the broken curve represents the former St. Louis rule of sewer capacity computed according to the newer and better formula. (Plate XVIII.)

As a matter of experience no St. Louis sewer of size greater than 2 feet by 3 has proved seriously insufficient which has been proportioned by the rule, but the probability of an over-allowance in the larger sizes is suggested by the fact that the curve of volume expected under the rule is concave to the axis of ordinates.

Table No. 2 (see page 187) presents data taken from actual sewers, from which Table have been plotted the column of "Capacity of sewers" as ordinates to the "Areas drained" as abscissas in (Plate XVIII) diagram of "Volume reaching sewers," and the cases of known insufficiency have been distinguished by inclosing the points.

* The maximum discharge of a circular conduit is computed to occur when the free arc is 60 degrees, depth .93³ per cent., and hydraulic mean depth 0.2914 of the diameter.

## TABLE No. 1.

| Diameter of sewer. | Discharge of sewer if slope = 0.50 in 100. | | | Discharge of sewer if slope = 1.0 in 100. | | | Discharge of sewer if slope = 2.0 in 100. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Moore *b*. | Moore *a*. | Moore *a*. / Moore *b*. | Moore *b*. | Moore *a*. | Moore *a*. / Moore *b*. | Moore *b*. | Moore *a*. | Moore *a*. / Moore *b*. | |
| Ft. | | | | | | | | | | |
| 1 | 2.86 | 2.27 | 0.79[4] | 4.05 | 3.21 | 0.79[2] | 5.73 | 4.55 | 0.79[4] | Pipe sewers. $n$ in formula for discharge = 0.015. |
| 1.25 | 5.27 | 3.98 | 0.75[8] | 7.46 | 5.62 | 0.75[3] | 10.55 | 7.94 | 0.75[2] | |
| 1.50 | 8.67 | 6.26 | 0.72[2] | 12.64 | 8.86 | 0.70[1] | 17.35 | 12.52 | 0.72[2] | |
| 1.75 | 13.34 | 9.21 | 0.69[0] | 18.87 | 13.12 | 0.69[5] | 26.68 | 18.41 | 0.69[0] | |
| 2.0 | 19.15 | 12.85 | 0.67[1] | 27.09 | 18.18 | 0.67[1] | 38.31 | 25.71 | 0.67[1] | |
| 2.5 | 29.95 | 22.46 | 0.75[0] | 42.35 | 31.76 | 0.75[0] | 59·90 | 44.92 | 0.75[0] | |
| 3.0 | 50.02 | 35.43 | 0.70[8] | 70.80 | 50.10 | 0.70[8] | 100.10 | 70.85 | 0.70[8] | |
| 3.5 | 75.0 | 52.1 | 0.69[4] | 106.1 | 73.7 | 0.69[4] | 150.1 | 104.2 | 0.69[4] | |
| 4.0 | 109.9 | 72.7 | 0.66[9] | 155.4 | 102.9 | 0.66[2] | 217.0 | 145.5 | 0.67[0] | |
| 4.5 | 152.3 | 97.6 | 0.64[1] | 215.4 | 138.1 | 0.64[1] | 302.0 | 195.3 | 0.64[8] | |
| 5.0 | 203.2 | 127.0 | 0.62[5] | 288.4 | 179.7 | 0.62[3] | 406.4 | 251.7 | 0.61[9] | Brick sewers. $n$ in formula for discharge = 0.013. |
| 5.5 | 260.3 | 161.2 | 0.61[9] | 368.1 | 228.0 | 0.61[9] | ..... | ..... | ..... | |
| 6.0 | 329.4 | 200.4 | 0.60[9] | 465.9 | 283.4 | 0.60[8] | ..... | ..... | ..... | |
| 6.5 | 407.1 | 244.8 | 0.60[1] | 575.7 | 346.2 | 0.60[1] | ..... | ..... | ..... | |
| 7.0 | 494.8 | 294.6 | 0.59[5] | 699.8 | 416.7 | 0.59[5] | ..... | ..... | ..... | |
| 8.0 | 704.1 | 411.4 | 0.58[4] | 995.8 | 581.8 | 0.58[4] | ..... | ..... | ..... | |
| 9.0 | 958.6 | 552.3 | 0.57[6] | 1 356 | 781.0 | 0.57[6] | ..... | ..... | ..... | |
| 10 | 1 264 | 718.7 | 0.56[9] | 1 788 | 1 017 | 0.56[9] | ..... | ..... | ..... | Brick sewer. $n$ = 0.013. |
| 12 | 1 984 | 1 134 | 0.57[1] | 2 806 | 1 603 | 0.57[1] | ..... | ..... | ..... | |
| 12 x 14 | 2 228 | 1 430 | 0.64[2] | 3 152 | 2 023 | 0.64[1] | ..... | ..... | ..... | Stone side walls and invert. $n$ = 0.012. |
| 15 x 18 | 4 000 | 2 513 | 0.62[8] | 5 656 | 3 554 | 0.62[8] | ..... | ..... | ..... | Timber bottom. |
| 15 x 20 | 4 901 | 3 203 | 0.65[3] | 6 931 | 4 530 | 0.65[3] | ..... | ..... | ..... | |

Some cases of over-charged sewer are exceptional, in that they are not due to want of capacity at the place where overcharge was observed, but to the transmitted effect of insufficiency at some other part of the sewer. Gorging in other cases arises from improper intersections: two streams meet in such a way as to destroy their velocity, hence the velocity below the junction is much less than that which the grade should give, and the tributary sewers are also choked. Setting aside these cases, which are indicated by asterisks in Table No. 2, a curve can be drawn which leaves all the inclosed points below its trace. A few uninclosed points are also found below, but these are cases of sewer not yet tested, since the areas they drain are mostly unimproved. The curve of the diagram is

$$Q = 0.75 \times 2.75 \sqrt[5]{15\ A^4}$$

$Q$ being the quantity of water reaching the sewer per second or the required capacity of the sewer, and $A$ the area drained. In symbols this equation would be written

$$Q = c\,\gamma \sqrt[5]{s\ A^4} = A\,c\,\gamma \sqrt[5]{\frac{s}{A}}$$

in which $c$ = the proportion of rain-fall that will reach the sewers; that is, it makes allowance for loss by evaporation, absorption and retention. Its value for any locality is a matter of judgment after taking into consideration the season at which the heaviest rain-fall occurs; the condition of surface paved or naked; the soil, porous or impenetrable; the use of ground, urban or suburban, park, lawn, etc. For St. Louis the proportion is three-fourths of the rain-fall.

The symbol $\gamma$ stands for the number of cubic feet of water falling upon an acre of surface per second during the period of greatest intensity of rain. Practically it is the same as the rate of rain-fall in inches per hour. St. Louis is liable to have rains at the rate of 2¾ inches per hour, and $\gamma$ is taken to be 2.75 cubic feet per second.

The mean surface grade in feet in a thousand is represented by $s$, and, as has been stated, area is represented by $A$.

The product of the factors not under the radical represents the quantity of water which the sewer must take, and the factor under the radical is the rate of arrival.

The form is like the well-known Burkli-Zeigler formula,

$$q = c\,\gamma\,\sqrt[5]{\frac{s}{A}},$$

in which $q$ is the quantity per acre reaching sewers, hence

$$Q = A\,q = c\,\gamma\,\sqrt[5]{s\,A^3}.$$

For comparison I have made Table No. 3, in which the second column is the actual allowance made by the St. Louis rule; the third column, the Burkli-Zeigler formula; and the fourth the preferred curve, $Q = 0.75 \times 2.75\,\sqrt[5]{s\,A^4}$, for St. Louis conditions.

TABLE No. 3.

| Acres. | Old Rule St. Louis. | Burkli-Zeigler. | New Rule St. Louis. | Acres. | Old Rule St. Louis. | Burkli-Zeigler. | New Rule St. Louis. |
|---|---|---|---|---|---|---|---|
| 5 | 6.7 | 13.6 | 12.8 | 1 100 | ..... | 775.3 | 961 |
| 10 | 13.9 | 22.8 | 22.9 | 1 200 | ..... | 827.6 | 1 030 |
| 15 | 20.4 | 30.94 | 30.94 | 1 300 | ..... | 878.8 | 1 098 |
| 20 | 26.8 | 38.4 | 38.9 | 1 400 | ..... | 929.0 | 1 165 |
| 25 | 33.4 | 45 4 | 46.5 | 1 500 | ..... | 978.3 | 1 232 |
| 30 | 40.4 | 52 0 | 53.9 | 1 750 | ..... | 1 098 | 1 393 |
| 40 | 55 0 | 64.5 | 67.8 | 2 000 | ..... | 1 214 | 1 550 |
| 50 | 70.0 | 76.3 | 81.0 | 2 250 | ..... | 1 326 | 1 704 |
| 60 | 85.7 | 87.5 | 93.8 | 2 500 | ..... | 1 435 | 1 853 |
| 70 | 101.5 | 98.2 | 106.1 | 2 750 | ..... | 1 541 | 2 000 |
| 80 | 118.3 | 108.6 | 118.0 | 3 000 | ..... | 1 645 | 2 145 |
| 90 | 133.6 | 118.6 | 129.7 | 3 250 | ..... | 1 747 | 2 286 |
| 100 | 150 | 128.4 | 141.1 | 3 500 | ..... | 1 847 | 2 426 |
| 125 | 192 | 151.7 | 168.7 | 3 750 | ..... | 1 945 | 2 564 |
| 150 | 234 | 174.0 | 195.2 | 4 000 | ..... | 2 042 | 2 699 |
| 175 | 278 | 195.3 | 220.8 | 4 250 | ..... | 2 137 | 2 833 |
| 200 | 321 | 215.9 | 245.7 | 4 500 | ..... | 2 230 | 2 966 |
| 250 | 410 | 255.2 | 293.7 | 4 750 | ..... | 2 323 | 3 097 |
| 300 | 501 | 292.6 | 339 9 | 5 000 | ..... | 2 414 | 3 227 |
| 350 | 588 | 328.4 | 384.5 | 5 500 | ..... | 2 592 | 3 483 |
| 400 | 676 | 363.0 | 427.8 | 6 000 | ..... | 2 767 | 3 734 |
| 450 | 765 | 396.6 | 470.1 | 6 500 | ..... | 2 938 | 3 981 |
| 500 | 855 | 429.2 | 511.4 | 7 000 | ..... | 3 106 | 4 224 |
| 550 | 946 | 461.0 | 552.0 | 7 500 | ..... | 3 271 | 4 463 |
| 600 | 1 038 | 492.1 | 591.8 | 8 000 | ..... | 3 433 | 4 700 |
| 700 | ..... | 552.4 | 669.4 | 8 500 | ..... | 3 593 | 4 933 |
| 800 | ..... | 610.6 | 744.9 | 9 000 | ..... | 3 750 | 5 165 |
| 900 | ..... | 667.0 | 818.5 | 9 500 | ..... | 3 906 | 5 392 |
| 1 000 | ..... | 721.8 | 890.5 | 10 000 | ..... | 4 059 | 5 619 |

The Burkli-Zeigler formula was derived from a comparison of discharge from comparatively small areas. For areas less than fifty acres it would apply to the St. Louis experience, but its failure is apparent when large areas, 1 000 acres or more, are considered. The St. Louis rule it will be noticed makes smaller allowance for discharge than the Burkli-Zeigler for areas less than sixty acres, and less than the new rule up to eighty acres, and yet but few cases of deficient size of sewers draining

small areas appear in the table. This may be accounted for by the fact that the tops of small sewers lie, as a rule, deeper below the cellars adjoining than do the tops of large sewers, and consequently they may run under a head and no one be inconvenienced; also it must be remembered that very few small sewers appear in the table. If opportunity occurs I hope to extend the study to the smaller sizes also.

In connection with such studies the query often arises: Does the velocity in sewers attain the value indicated by formulas which depend upon slope? Some doubt that it does, and claim that angular blocks of stone would be moved by velocities such as formulas call for, and that there is no evidence that such blocks are moved. In 1883 an examination of Mill Creek sewer found several large rocks containing as much as ten cubic feet, which could not be accounted for, except on the supposition that they had been carried to the place where found by the current. They were sledged into pieces of moderate size, which were not found at a subsequent examination. In Rocky Branch sewer two rocks 36 x 36 x 9 inches were found, in 1883, which were not broken up; one is not now in the sewer, the other has moved 23 feet. The rocks were limestone, weighing about 150 pounds per cubic foot. Again, while putting in a granite invert in Camp Spring sewer, a storm came when a section of invert was unfinished, the whole unfinished section of paving disappeared. The blocks were found afterwards in an alternate branch about 1 200 feet from the spot they started from. The sewer was 7 x 8 feet and its gradient .0124. The maximum velocity under the conditions would, by formula, be 21.5 feet per second. The Rocky Branch sewer may have had a velocity of 19.8 feet per second, and Mill Creek 17.6, according to formula, and the movement of the rocks seems to show that some such velocity must have been reached.

Table No. 4 gives particulars as to form, also the hydraulic factors for the several sewers used in St. Louis. The hydraulic factors are for the sewer at its maximum discharge without head.

By the factors given, a table of capacities for various grades was computed, which I have platted as diagrams of "Capacities of Sewers." The use of the diagrams needs no explanation. (See Plate XVIII.)

## TABLE No. 4.

| Size. | Form data. | | | Hydraulic factors. | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Rad. arch. | Rad. invert. | Rad. sides. | Area. | Wet perimeter. | $r$ | $\sqrt{r}$. | $n$. | $c$. |
| **Pipe sewers.** | | | | Sq. ft. | Ft. | Ft. | Ft. | | |
| 6″ | ..... | ..... | ..... | .1905 | 1.309 | .1457 | .3817 | .012 | 83.2 |
| 8″ | ..... | ..... | ..... | .355 | 1.745 | .1942 | .4407 | .012 | 88.4 |
| 9″ | ..... | ..... | ..... | .430 | 1.963 | .2185 | .4674 | .012 | 93.0 |
| 10″ | ..... | ..... | ..... | .530 | 2.356 | .2428 | .4938 | .012 | 95.4 |
| 12″ | ..... | ..... | ..... | 0.763 | 2.618 | .2914 | .5398 | .012 | 98.3 |
| 15″ | ..... | ..... | ..... | 1.192 | 3.272 | .3642 | .6035 | .012 | 103.7 |
| 18″ | ..... | ..... | ..... | 1.716 | 3.927 | .4371 | .6611 | .012 | 108.1 |
| 21″ | ..... | ..... | ..... | 2.336 | 4.582 | .5099 | .7141 | .012 | 113.1 |
| 24″ | ..... | ..... | ..... | 3.051 | 5.236 | .5828 | .7634 | .012 | 116.3 |
| **Brick sewers.** | | | | | | | | | |
| 2′ × 3′ | 1′ 0″ | 0′ 9″ | 4′ 0″ | 4.693 | 6.874 | .683 | .826 | .013 | 109.2 |
| 2′ 6″ × 3′ 6″ | 1′ 3″ | 1′ 0″ | 4′ 2½″ | 6.829 | 8.199 | .833 | .913 | .013 | 113.5 |
| 3′ × 4′ | 1′ 6″ | 1′ 4⅝″ | 3′ 9″ | 9.249 | 9.551 | .968 | .984 | .013 | 116.6 |
| 3′ 6″ × 4′ 6″ | 1′ 9″ | 1′ 5″ | 4′ 3″ | 12.313 | 11.042 | 1.115 | 1.056 | .013 | 119.5 |
| 4′ × 5′ | 2′ 0″ | 1′ 8⅝″ | 4′ 9″ | 15.516 | 12.104 | 1.282 | 1.134 | .013 | 122.4 |
| 4′ 9″ | 2′ 4½″ | ..... | ..... | 17.211 | 12.435 | 1.384 | 1.176 | .013 | 123.8 |
| 5′ 0″ | 2′ 6″ | ..... | ..... | 19.069 | 13.090 | 1.457 | 1.208 | .013 | 124.8 |
| 5′ 3″ | 2′ 7½″ | ..... | ..... | 21.025 | 13.744 | 1.593 | 1.237 | .013 | 125.7 |
| 5′ 6″ | 2′ 9″ | ..... | ..... | 23.073 | 14.398 | 1.603 | 1.266 | .013 | 126.6 |
| 5′ 9″ | 2′ 10½″ | ..... | ..... | 25.217 | 15.053 | 1.675 | 1.294 | .013 | 127.5 |
| 6′ 0″ | 3′ 0″ | ..... | ..... | 27.459 | 15.708 | 1.748 | 1.322 | .013 | 128.3 |
| 6′ 3″ | 3′ 1½″ | ..... | ..... | 29.796 | 16.362 | 1.821 | 1.349 | .013 | 129.0 |
| 6′ 6″ | 3′ 3″ | ..... | ..... | 32.226 | 17.017 | 1.894 | 1.376 | .013 | 129.8 |
| 6′ 9″ | 3′ 4½″ | ..... | ..... | 34.754 | 17.671 | 1.967 | 1.402 | .013 | 130.5 |
| 7′ 0″ | 3′ 6″ | ..... | ..... | 37.374 | 18.326 | 2.040 | 1.428 | .013 | 131.1 |
| 7′ 3″ | 3′ 7½″ | ..... | ..... | 39.594 | 18.980 | 2.113 | 1.454 | .013 | 131.8 |
| 7′ 6″ | 3′ 9″ | ..... | ..... | 42.904 | 19.635 | 2.185 | 1.478 | .013 | 132.4 |
| 7′ 9″ | 3′ 10½″ | ..... | ..... | 45.810 | 20.289 | 2.258 | 1.503 | .013 | 132.9 |
| 8′ 0″ | 4′ 0″ | ..... | ..... | 48.813 | 20.944 | 2.331 | 1.527 | .013 | 133.5 |
| 8′ 3″ | 4′ 1½″ | ..... | ..... | 51.916 | 21.598 | 2.409 | 1.551 | .013 | 134.0 |
| 8′ 6″ | 4′ 3″ | ..... | ..... | 55.109 | 22.252 | 2.477 | 1.574 | .013 | 134.5 |
| 8′ 9″ | 4′ 4½″ | ..... | ..... | 58.394 | 22.899 | 2.550 | 1.597 | .013 | 135.0 |
| 9′ 0″ | 4′ 6″ | ..... | ..... | 61.782 | 23.559 | 2.623 | 1.619 | .013 | 135.5 |
| 9′ 3″ | 4′ 7½″ | ..... | ..... | 65.258 | 24.210 | 2.695 | 1.642 | .013 | 136.0 |
| 9′ 6″ | 4′ 9″ | ..... | ..... | 68.833 | 24.653 | 2.768 | 1.664 | .013 | 136.5 |
| 9′ 9″ | 4′ 10½″ | ..... | ..... | 72.504 | 25.520 | 2.841 | 1.685 | .013 | 136.9 |
| 10′ 0″ | 5′ 0″ | ..... | ..... | 76.274 | 26.180 | 2.914 | 1.707 | .013 | 137.3 |
| 10′ 3″ | 5′ 1½″ | ..... | ..... | 80.131 | 26.832 | 2.987 | 1.728 | .013 | 137.7 |
| 10′ 6″ | 5′ 3″ | ..... | ..... | 84.087 | 27 327 | 3.060 | 1.749 | .013 | 138.1 |
| 11′ 0″ | 5′ 6″ | ..... | ..... | 92.287 | 28.776 | 3.205 | 1.790 | .013 | 138.9 |
| 12′ 0″ | 6′ 0″ | ..... | ..... | 109.829 | 31.414 | 3.497 | 1.830 | .013 | 139.6 |
| **Brick and stone.** | | | Batter. | | | | | | |
| 12′ × 14′ | 7′ 0″ | 12′ | 1 in 12 | 132.665 | 35.419 | 3.745 | 1.935 | .015 | 122.8 |
| 15′ × 18′ | 9′ 0″ | 15′ | 1 in 12 | 208.120 | 44.72 | 4.654 | 2.157 | .015 | 126.0 |
| 15′ × 20′ | 10′ 0″ | Flat. | 1 in 12 | 249.204 | 51.60 | 4.830 | 2.197 | .015 | 126.6 |
| | | | Radius. | | | | | | |
| 15′ × 15′ | 7′ 6″ | " | 12′ 6″ | 177.009 | 41.534 | 4.262 | 2.064 | .015 | 124.7 |
| | | | Batter. | | | | | | |
| 10′ × 15′ | 4′ 0″ and 10′ 0″ | " | 1 in 12 | 130.461 | 37.12 | 3.515 | 1 875 | .015 | 121.8 |
| 10′ × 11′ | 5′ 0″ | " | 1 in 12 | 94.004 | 31.55 | 2.979 | 1.727 | .015 | 119.7 |

## TABLE No. 2.

### DATA FROM ST. LOUIS SEWERS.

| Length of sewer. Feet. | Size. Feet. | Mean grade. Feet per 1 000. | Area to be drained in acres = $A$. | Capacity of sewer in cubic feet per second. $Q = a\,c\sqrt{rs}$. (Kutter.) | Capacity required = $Q'$. $Q' = 0.75 \times 2.75\sqrt[6]{15\,A'}$. | |
|---|---|---|---|---|---|---|
| | | | **Mill Creek Sewer.** | | | |
| 770 | 12′×14′ | 2.50 | 1 500 | 1 550 | 1 225 | Not built, but under contract. |
| 3 656 | 15′×18′ | 1.25 | 3 549 | 1 980 | 2 225 | Built, but not in use. The drainage from 1 200 acres will be diverted. |
| 2 119 | 15′×20′ | 1.30 | 4 156 | 2 500 | 2 800 | Receives Compton ave. sewer. |
| 3 984 | 15′×20′ | 2.30 | 5 099 | 3 320 | 3 275 | Receives Joab and Ohio avenue sewers. |
| 4 639 | 15′×20′ | 2.50 | 6 204 | 3 450 | 3 840 | Receives Camp Spring and 13th street sewers, and is overcharged. |
| 4 615 | 15′×20′ | 5.60 | 6 311 | 5 180 | 3 890 | Elevation at mouth, — 28′.3. Highest water in river, + 7′.56. Back-water in spring. |
| | | | **Compton Avenue Sewer.** | | | |
| 1 570 | 5′×6′ | 10 70 | 247 | 380 | 295 | |
| 1 350 | 5′×6′ | 5.90 | 284 | 253 | 330 | Often overcharged. |
| 2 078 | 7′3″ | 12.10 | 400 | 830 | 435 | |
| | | | **Joab Street Sewer.** | | | |
| 969 | 3′6″ | 16.00 | 66 | 133 | 101 | |
| 2 423 | 4′×5′ | 16.30 | 208 | 270 | 255 | |
| | | | **Ohio Avenue Sewer.** | | | |
| 803 | 5′.$^{8}_{10}$ | 3.00 | 93 | 230 | 132 | |
| 650 | 6′ | 3.00 | 111 | 256 | 153 | |
| 1 302 | 7′ | 5.40 | 243 | 540 | 288 | |
| 520 | 7′25 | 9.00 | 253 | 720 | 294 | |
| 2 766 | 7′.5″ | 12.10 | 436 | 920 | 459 | |
| | | | **Camp Spring Sewer.** | | | |
| 1 106 | 3′×4′ | 8.70 | 55 | 100 | 87 | Sewer overcharged.* |
| 1 257 | 4′×5′ | 13 50 | 161 | 248 | 207 | " |
| 1 064 | 6′×7′ | 23.40 | 197 | 870 | 245 | |
| 1 333 | 6′5×7′5 | 13.20 | 327 | 802 | 364 | |
| 1 299 | 7′×8′ | 12.40 | 396 | 932 | 423 | |
| 929 | 8′5″ | 4.00 | 516 | 733 | 524 | " * |
| | | | **Branch to Camp Spring.** | | | |
| 497 | 2′×3′ | 23.0 | 21 | 64 | 41 | |
| 424 | 2½′×3½′ | 14.6 | 49 | 86 | 80 | Sewer overcharged.* |
| | | | **Thirteenth Street Sewer.** | | | |
| 1 051 | 3′5″×5′ | 13.30 | 66 | 220 | 101 | |
| 600 | 5′ | 13.30 | 102 | 333 | 142 | |
| 404 | 6′ | 13.30 | 125 | 538 | 167 | |
| 1 805 | 6′ | 5.30 | 164 | 356 | 210 | |
| 1 055 | 6′×7′ | 16.00 | 207 | 729 | 254 | |

### Ninth Street Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 547 | 3½′×4½′ | 7.00 | 89 | 130 | 129 | |
| 420 | 5′5″×7′ | 5.00 | 121 | 370 | 163 | |

### Biddle Street Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 640 | 2′5″×3′5″ | 5.00 | 17 | 51 | 35 | |
| 2 265 | 3′×4′ | 3.40 | 82 | 60 | 120 | Sewer overcharged. |
| 3 650 | 4′×5′ | 10.00 | 100 | 215 | 140 | |
| 250 | 5′×7′ | 4.40 | 237 | 308 | 284 | |
| 950 | 7′×8′ | 3.50 | 441 | 496 | 462 | " " * |
| 680 | 9′ | 2.00 | 458 | 605 | 475 | " " * |
| 1 444 | 12′ | 1.74 | 657 | 1 165 | 640 | " " * |
| 604 | 12′ | 26.80 | 668 | ..... | 650 | |

### Northwestern Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 547 | 3′×4′ | 9.40 | 113 | 102 | 154 | Sewer overcharged. |
| 754 | 3′5″×4′5″ | 13.20 | 138 | 178 | 183 | " " |
| 282 | 4′2″×5′6″ | 13.20 | 147 | 390 | 193 | |

### Branch to Northwestern Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 180 | 2′×3′ | 8.70 | 20 | 40 | 40 | |
| 651 | 2′6″×3′6″ | 11.50 | 23 | 73 | 44 | |

### Cass Avenue Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 158 | 3′×4′ | 2.30 | 61 | 49 | 96 | Sewer overcharged. |
| 990 | 2½′×3½′ | 14.70 | 60 | 86 | 95 | |
| 1 325 | 4′×5′ | 5.00 | 94 | 151 | 134 | " " " |
| 910 | 5′×7′ | 5.00 | 159 | 330 | 204 | |
| 928 | 4′2″×5′6″ | 4.60 | 190 | 180 | 237 | " " |
| 1 087 | 8′ | 2.00 | 219 | 443 | 265 | |

### Chambers Street Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 640 | 2½′×3½′ | 14.50 | 51 | 85 | 83 | |
| 2 145 | 4′×5′ | 5.00 | 102 | 152 | 141 | |
| 1 894 | 4′×5′ | 28.10 | 162 | 362 | 207 | |

### Benton Street Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 085 | 5′6″×6′10″ | 3.70 | 123 | 320 | 164 | |
| 1 365 | 4′×5′6″ | 10.90 | 155 | 163 | 200 | Sewer overcharged. |
| 1 772 | 4′×5′6″ | 18.80 | 188 | 340 | 233 | |

### Grand Avenue Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 387 | 2′×3′ | 11.00 | ... | 45 | ... | |
| 530 | 2′6″×3′6″ | 6.50 | 12 | 56 | 24 | |
| 2 937 | 3′6″×4′6″ | 6.00 | 138 | 122 | 182 | Sewer overcharged. |
| 1 260 | 4′×5′ | 4.00 | 198 | 138 | 246 | " " |
| 1 197 | 5′×6′6″ | 4.00 | 236 | 266 | 283 | " " |
| 817 | 5′×6′6″ | 6.00 | 271 | 325 | 312 | " " |
| 880 | 5′×6′ | 6.00 | 304 | 256 | 343 | " " |

### Elliott Avenue Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 361 | 2′×3″ | 15.00 | 31 | 52 | 55 | Sewer overcharged. |
| 1 064 | 4′×5′ | 15.00 | 91 | 265 | 131 | |
| 1 300 | 5′×6′ | 11.40 | 185 | 392 | 231 | |
| 1 380 | 6′6″×8′6″ | 10.00 | 289 | 840 | 330 | |
| 1 193 | 7′×9′ | 10.00 | 623 | 995 | 610 | |

### Davis Street Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 635 | 2′6″×3′6″ | 5.00 | 43 | 48 | 73 | Area mostly parked. (Fair grounds.) |
| 1 679 | 3′×4′ | 5.00 | 62 | 75 | 96 | |
| 937 | 3′6″×4′6″ | 5.40 | 108 | 114 | 150 | |
| 2 143 | 4′×5′ | 11.70 | 155 | 231 | 200 | |

### Farrar Street Sewer.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 231 | 4′6″×5′6″ | 10.00 | 111 | 290 | 152 | |

**Rocky Branch Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 735 | 10'6" | 4.40 | 1 084 | 1 290 | 950 | |
| 1 400 | 10'6" | 5.50 | 1 723 | 1 506 | 1 520 | |
| 3 049 | 10'6" | 6.00 | 2 168 | 1 575 | 1 660 | |
| 940 | 12' | 7.00 | 2 201 | 2 350 | 1 680 | |
| 437 | 12' | 20.00 | 2 256 | .... | 1 720 | |
| 2 573 | 12' | 7.00 | 2 413 | 2 350 | 1 830 | |

**Branch on Broadway.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 932 | 2'×3' | 7.80 | 33 | 40 | 58 | Sewer overcharged. |
| 540 | 2'×3' | 10.00 | 46 | 43 | 77 | " " |
| 706 | 2'×3' | 16.60 | 51 | 55 | 83 | " " |
| 960 | 2'6"×3'6" | 16.00 | 66 | 90 | 102 | " " |

**Salisbury Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 770 | 2'×3' | 19.00 | 49 | 60 | 81 | Sewer overcharged. |
| 1 498 | 3'×4' | 8.40 | 91 | 98 | 131 | " " |

**Bremen Avenue Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 698 | 2'6"×3'6" | 15.00 | 54 | 87 | 87 | |
| 853 | 3'6"×4'6" | 10.00 | 87 | 155 | 128 | |
| 1 889 | 4'×5' | 6.00 | 129 | 168 | 172 | |

**Ferry Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 590 | 5'6" | 7.70 | 216 | 323 | 263 | |
| 1 179 | 5'6" | 14.00 | 251 | ... | 296 | |
| 935 | 5'×7' | 20.00 | 277 | .. | 317 | |
| 1 245 | 5'×6' | 5.50 | 338 | 274 | 373 | Sewer overcharged. |
| 2 130 | 3'×10' | 4.20 | 496 | 876 | 507 | |

**Gingrass Creek Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 366 | 2'6"×3'6" | 3.00 | 30 | 56 | 54 | |
| 1 062 | 3'6"×4'6" | 4.00 | 39 | 100 | 69 | |
| 780 | 4'×5' | 4.00 | 89 | 133 | 130 | |

**Rutger Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 188 | 3'×4' | 16.10 | 32 | 133 | 56 | |
| 2 140 | 3'6"×4'6" | 23.00 | 88 | 235 | 127 | |
| 1 035 | 4'×5' | 7.10 | 119 | 180 | 163 | |
| 979 | 4'×5' | 14.00 | 128 | 252 | 172 | |

**Miller Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 315 | 2'×3' | 42.5 | 25 | 90 | 48 | |
| 1 046 | 2'×4' | 11.0 | 42 | 73 | 71 | |
| 1 287 | 3'×4' | 10.70 | 62 | 108 | 97 | |

**Carroll Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 069 | 2'6"×3'6" | 15·70 | 44 | 87 | 76 | |
| 616 | 2'6"×3'6" | 9.30 | 52 | 68 | 84 | |
| 1 228 | 3'×4' | 27.10 | 70 | 173 | 106 | |
| 165 | 3'6"×4'6" | 34.80 | 74 | 288 | 112 | |
| 2 480 | 4'×5' | 12.70 | 149 | 241 | 196 | |

**Trudeau Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 040 | 2'6"×3'6" | 16.00 | 120 | 112 | 163 | Sewer overcharged. |
| 2 351 | 4'×5' | 27.60 | 192 | 360 | 240 | |
| 2 832 | 5'×6' | 8.00 | 244 | 330 | 288 | |
| 869 | 6'×7'6" | 16.70 | 258 | 815 | 302 | |

**Barton Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 599 | 2'6"×3'6" | 36.30 | 44 | 132 | 76 | |
| 370 | 3'×4' | 18.00 | 49 | 140 | 82 | |
| 2 058 | 4'6" | 7.00 | 98 | 168 | 136 | |
| 805 | 4'9" | 18.20 | 109 | 330 | 150 | |

**Louisa Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 516 | 2'6"×3'6" | 27.30 | 54 | 114 | 88 | |
| 2 272 | 4'×5' | 6.80 | 183 | 175 | 230 | |
| 962 | 4'9" | 10.80 | 198 | 273 | 245 | |

**Arsenal Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 718 | 4' | 10.30 | 96 | 156 | 136 | |
| 1 180 | 5' | 9.00 | 183 | 273 | 202 | |
| 1 967 | 6' | 6.00 | 245 | 360 | 290 | |
| 1 926 | 7'6" | 4.10 | 548 | 533 | 552 | |
| 3 099 | 8'0" | 15.70 | 710 | 1 160 | 680 | |

**Illinois Avenue Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 630 | 2'×3' | 9.20 | 32 | 42 | 57 | |
| 657 | 4'0" | 8.70 | 72 | 147 | 108 | |
| 660 | 5'6" | 7.40 | 165 | 319 | 212 | |
| 661 | 6'0" | 5.00 | 181 | 329 | 226 | |
| 141 | 7'×8' | 5.00 | 288 | 592 | 328 | |

**Potomac Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 517 | 2'6" | 26.00 | 21 | 69 | 42 | |
| 495 | 3'0" | 12.50 | 28 | 78 | 52 | |

**Cherokee Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 614 | 2'6"×5'6" | 18.50 | 40 | 98 | 69 | |
| 1 352 | 3'6" | 20.00 | 53 | 150 | 86 | |

**Wyoming Street Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 972 | 2'×3' | 27.00 | 47 | 70 | 78 | |
| 951 | 2'9"×3'5" | 10.00 | 54 | 83 | 87 | |
| 658 | 4'0" | 16.10 | 64 | 200 | 109 | |
| 991 | 4'6" | 16.10 | 92 | 272 | 133 | |

**Branch to Arsenal Street North of Lynch Street.**

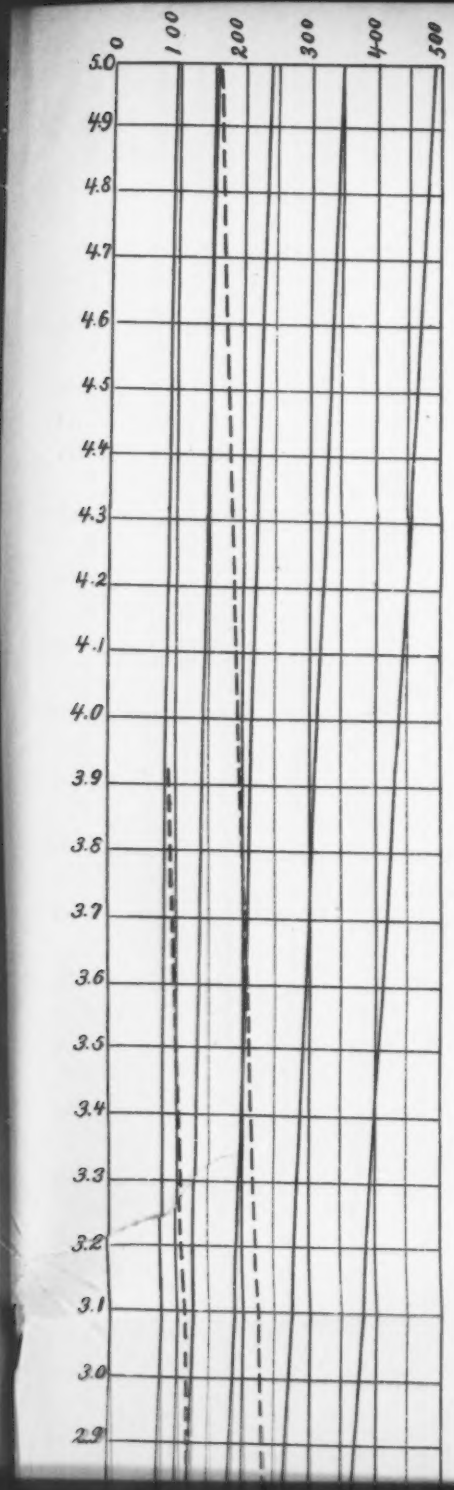
| | | | | | | |
|---|---|---|---|---|---|---|
| 872 | 2'×3' | 13.60 | 36 | 50 | 62 | Sewer overcharged. |
| 214 | 3'0" | 5.00 | 49 | 48 | 82 | " " |

**Southern Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 634 | 4'×5' | 10.20 | 122 | 214 | 165 | |
| 1 484 | 5'×7' | 7.10 | 217 | 390 | 265 | |
| 2 669 | 10'×11' | 6.00 | 766 | 1 508 | 720 | |
| 1 556 | 10'×11' | 13.30 | 816 | 2 200 | 750 | |

**Vanceventer Avenue Sewer.**

| | | | | | | |
|---|---|---|---|---|---|---|
| 329 | 2'6"×3'6" | 5.50 | 37 | 50 | 66 | These sewers are under construction. The sizes were proportioned to drainage areas strictly according to the former St. Louis rules and so built, except the last 3 350 feet, where grade was increased from 4 to 5 feet per thousand after the size was determined. |
| 344 | 3'×4' | 5.50 | 48 | 79 | 80 | |
| 314 | 3'6"×4'6" | 6.00 | 57 | 122 | 92 | |
| 423 | 4'×5' | 5.50 | 69 | 161 | 106 | |
| 516 | 4'9" | 4.00 | 99 | 162 | 140 | |
| 436 | 5'3" | 4.00 | 129 | 208 | 173 | |
| 402 | 5'6" | 4.00 | 152 | 233 | 197 | |
| 575 | 6'0" | 4.00 | 196 | 295 | 243 | |
| 655 | 6'3" | 4.00 | 214 | 328 | 262 | |
| 1 493 | 6'6" | 4.00 | 230 | 365 | 276 | |
| 595 | 7'9" | 4.00 | 379 | 576 | 410 | |
| 361 | 8'0" | 4.00 | 419 | 628 | 444 | |
| 508 | 8'3" | 5.00 | 442 | 768 | 464 | |
| 2 848 | 8'6" | 5.00 | 572 | 825 | 570 | |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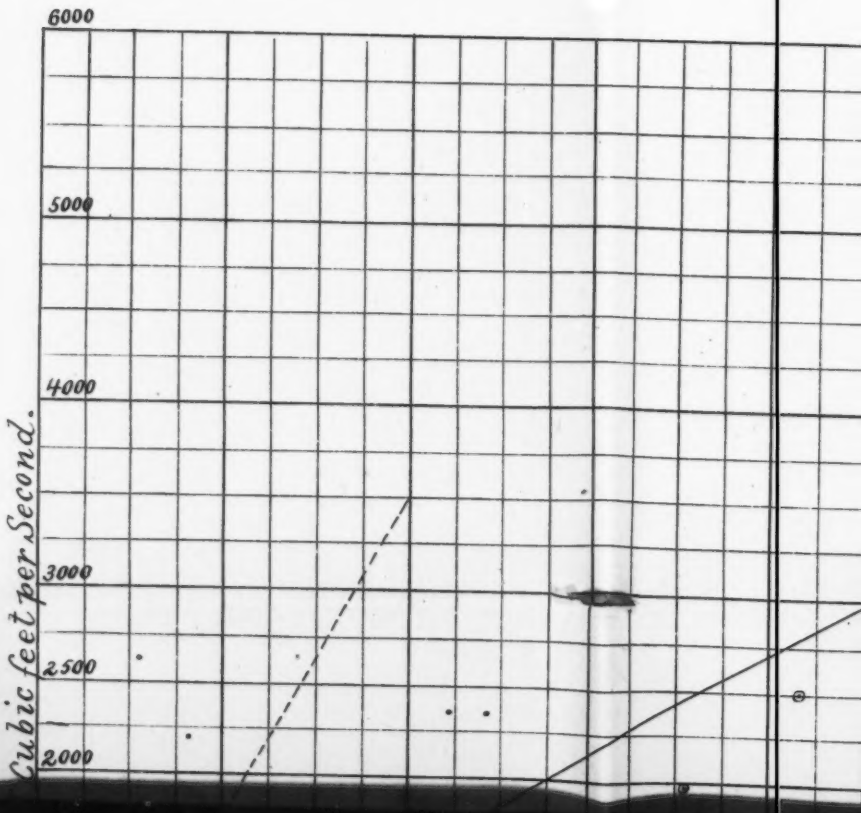
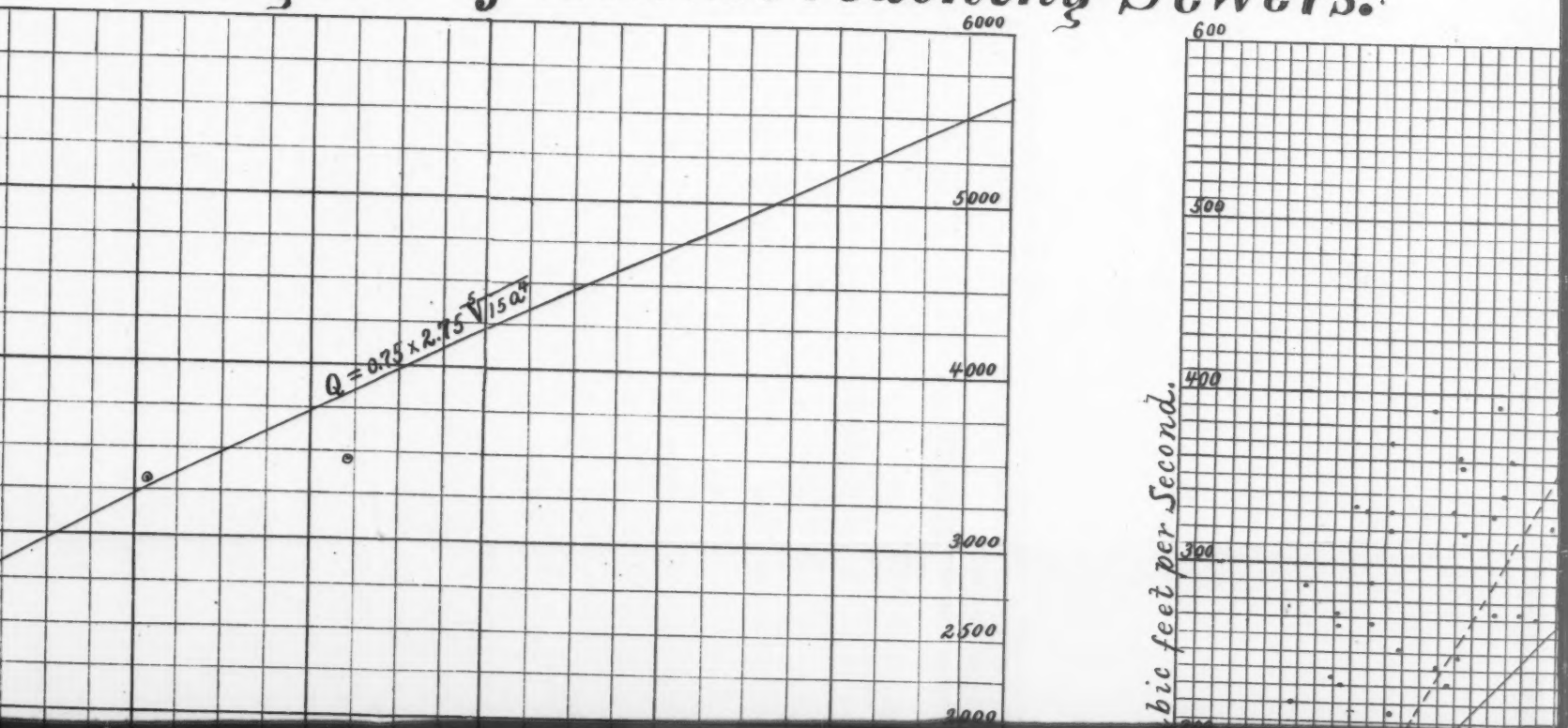
3.0
2.9


6000
5000
4000
3000
2500
2000
Cubic feet per Second.

# Diagram of Volume reaching Sewers.



# Diagram of Volume reaching

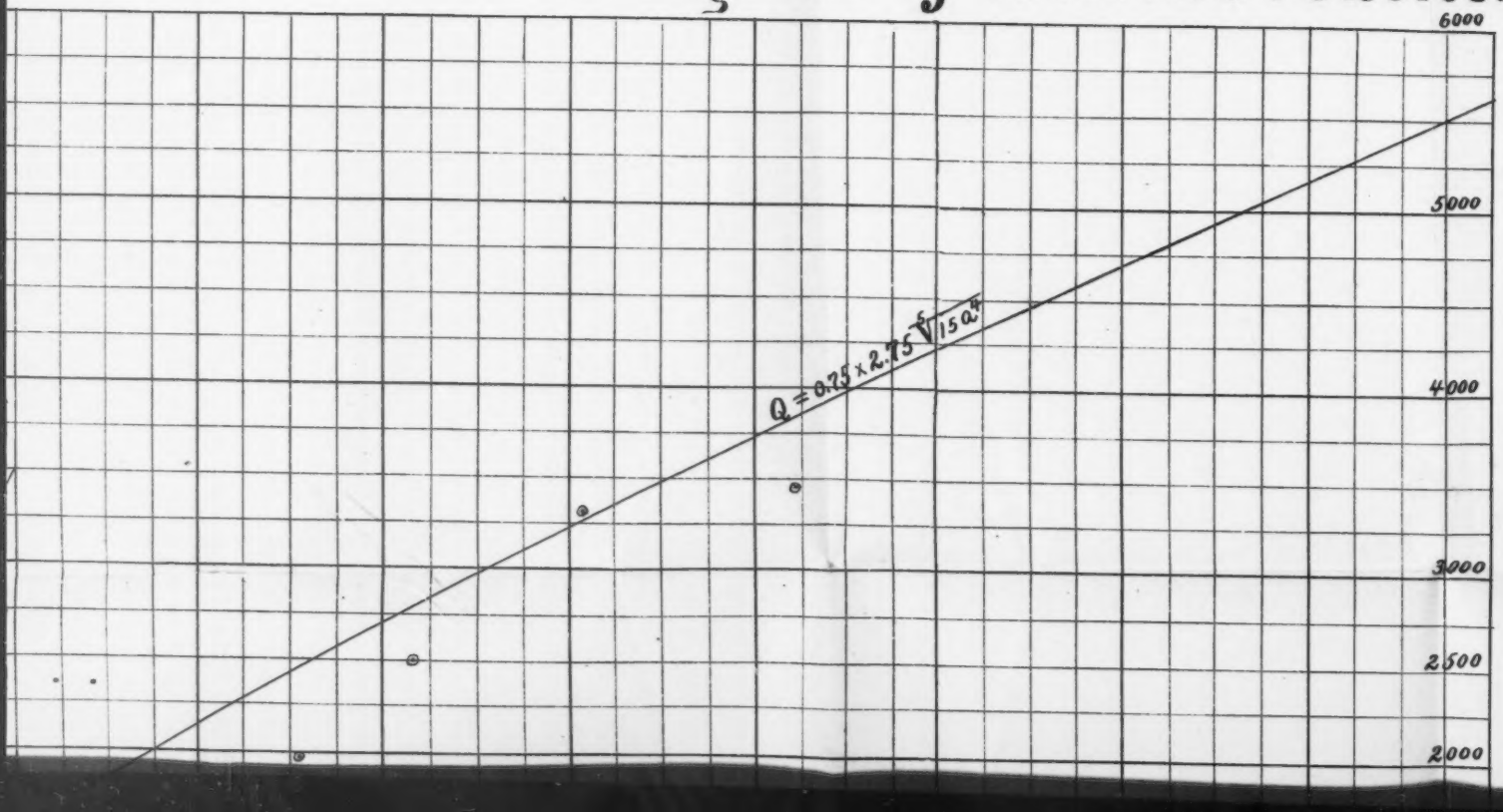
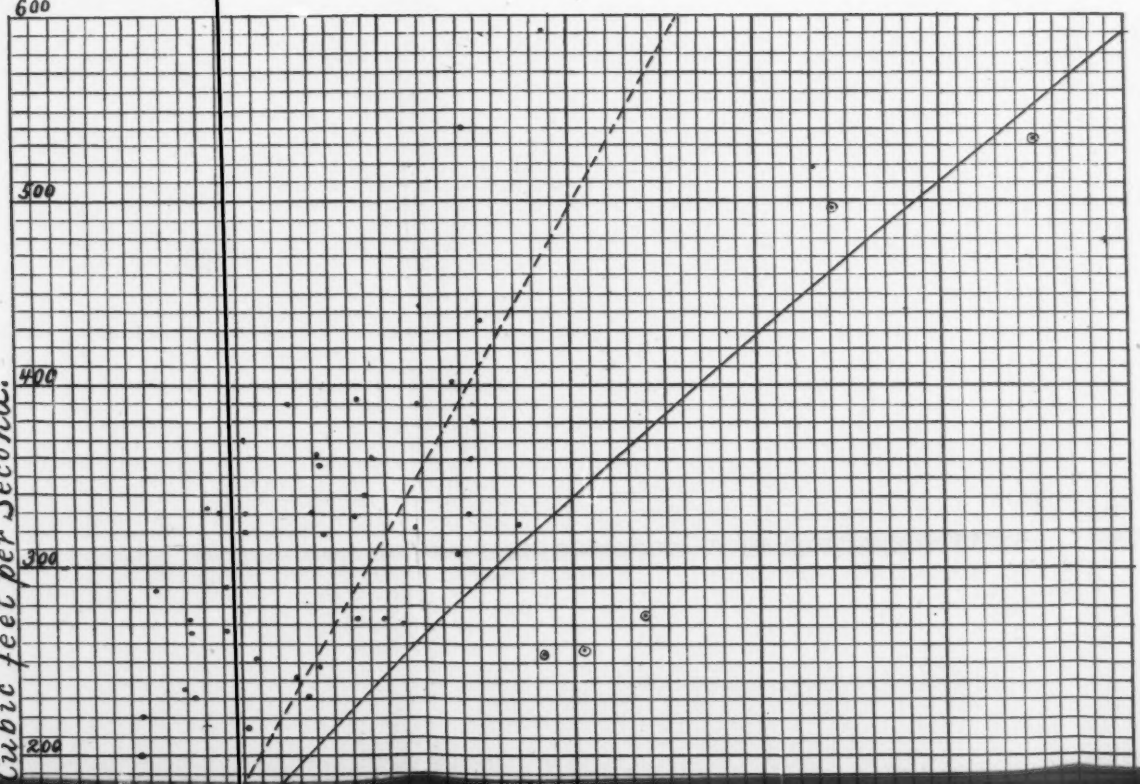
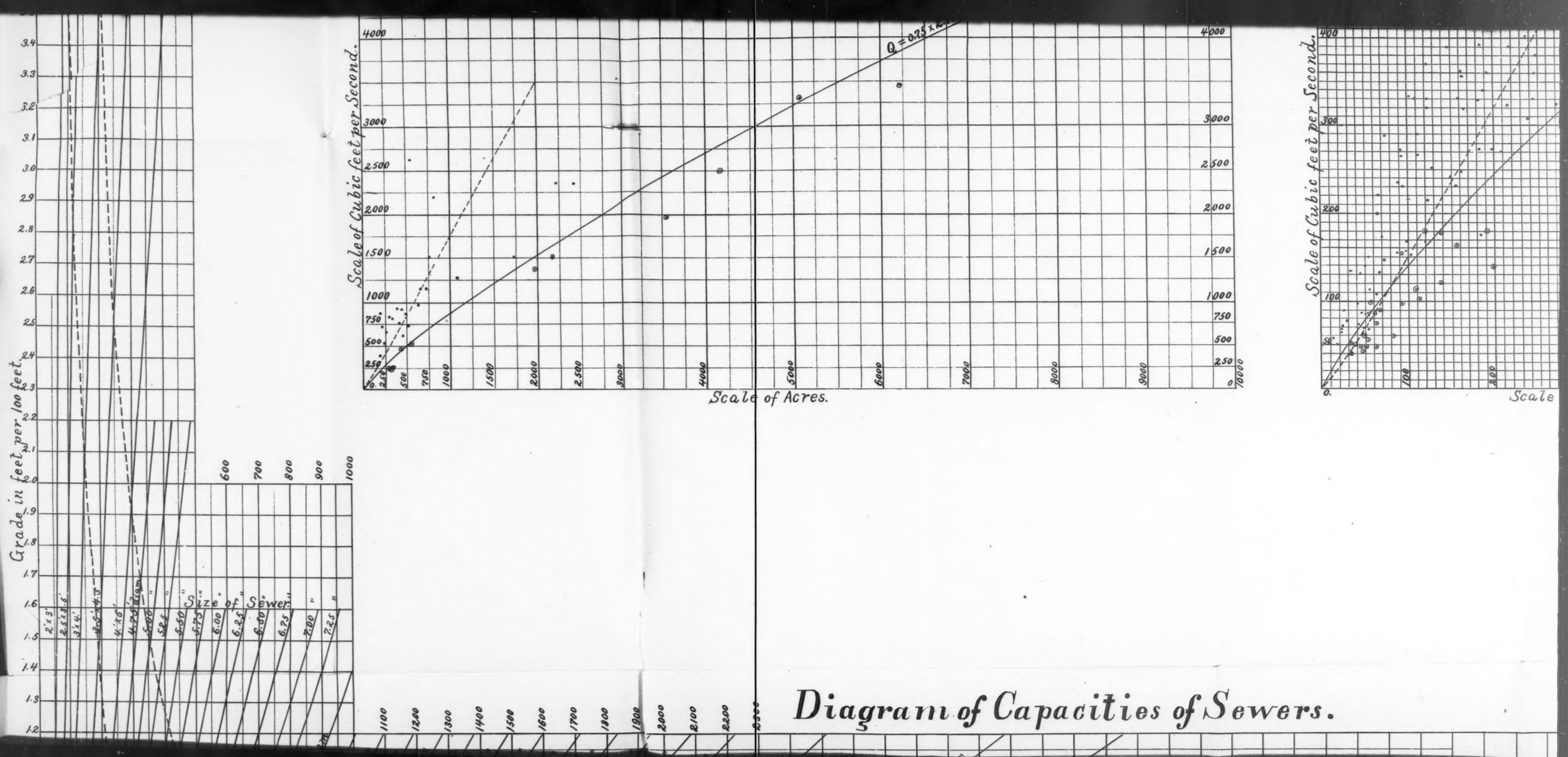


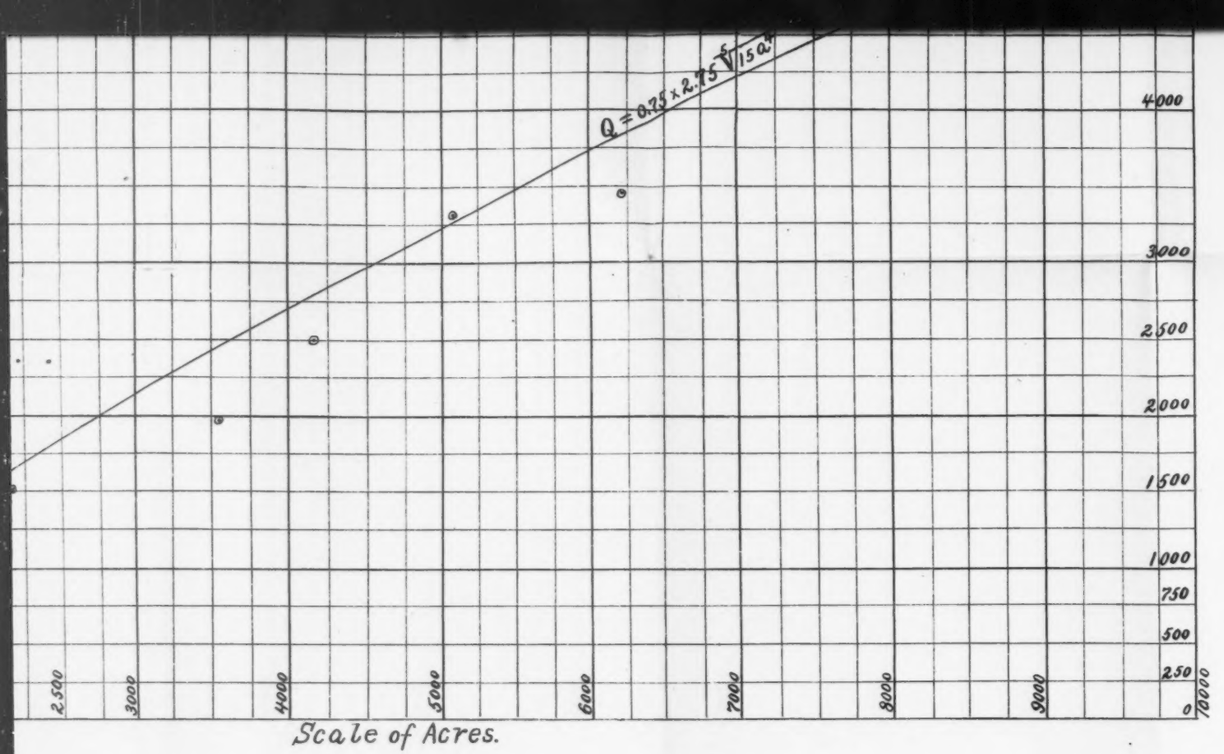
PLATE XVIII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XVI Nº 358.
Mc MATH ON
SIZE OF SEWERS.

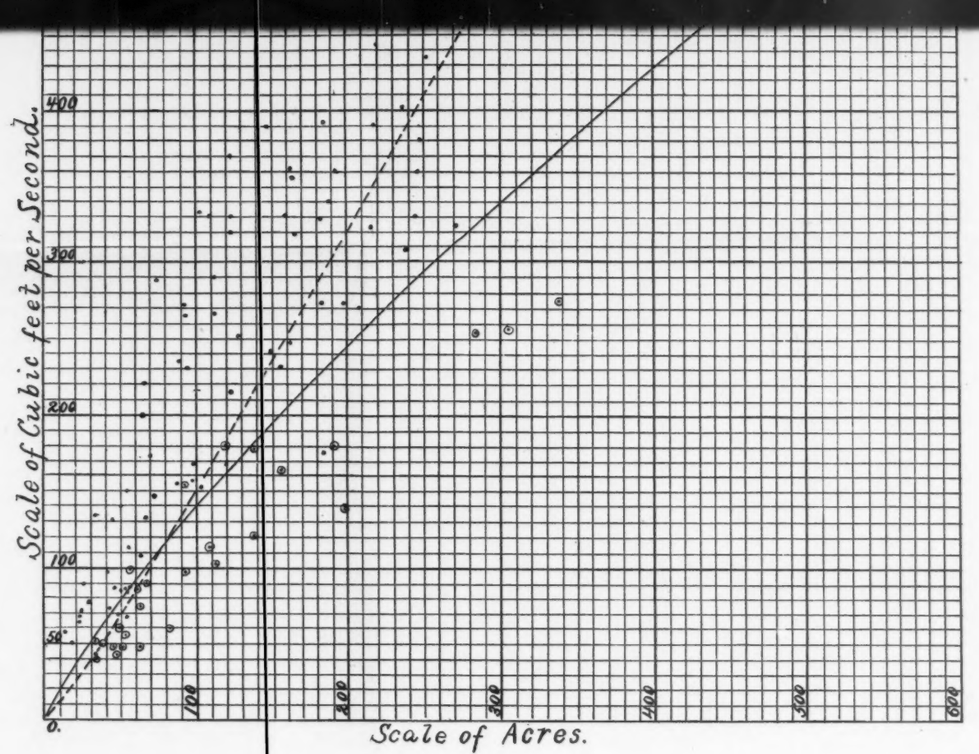
# g Sewers.






# Diagram of Capacities of Sewers.




# Diagram of Capacities of Sewers.

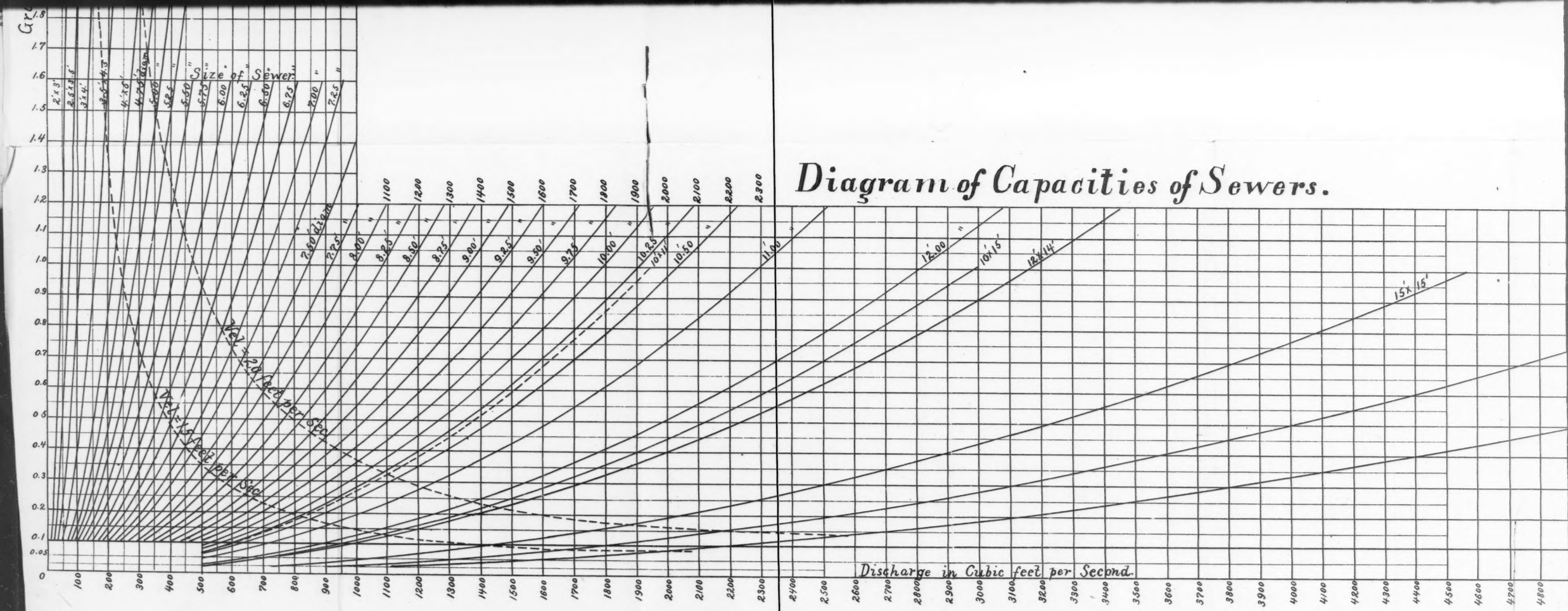
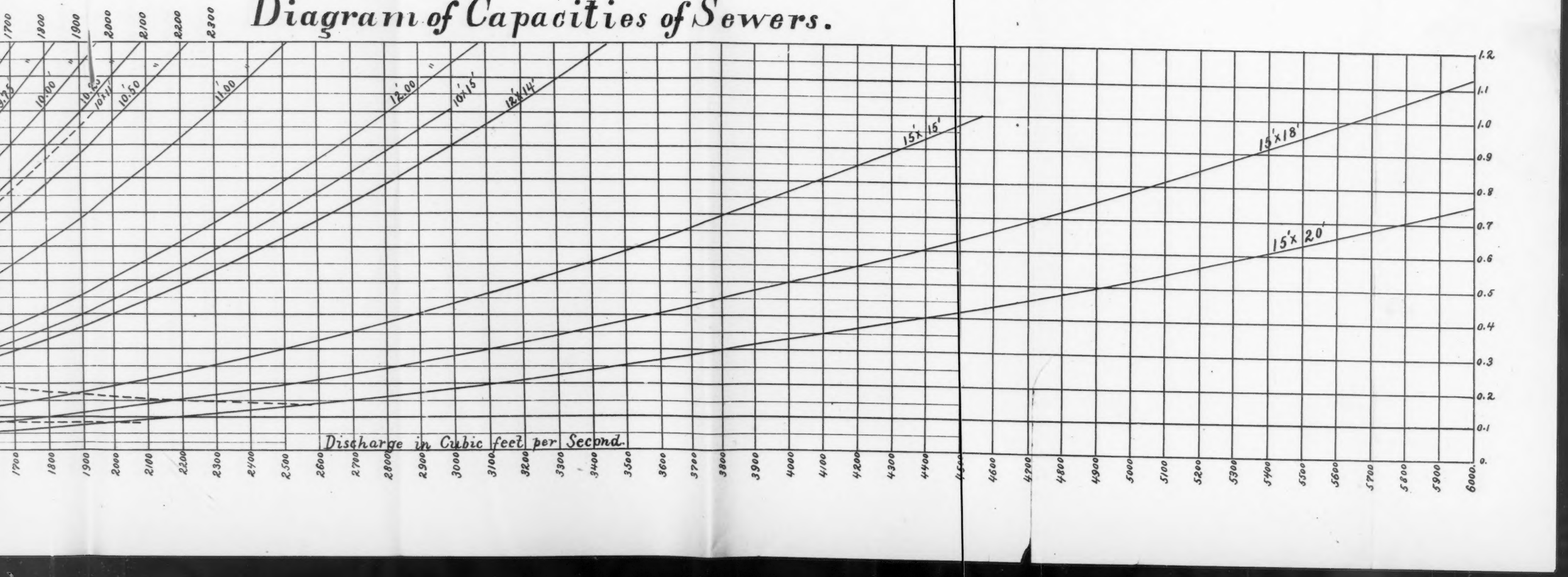


Diagram of Capacities of Sewers.
Size of Sewer.
2'x3'
2.5'x3.5'
3'x4'
3.5'x4.5'
4'x5'
4.5'x5.5'
5.00 "
5.25 "
5.50 "
5.75 "
6.00 "
6.25 "
6.50 "
6.75 "
7.00 "
7.25 "
7.50 diam.
7.75 "
8.00 "
8.25 "
8.50 "
8.75 "
9.00 "
9.25 "
9.50 "
9.75 "
10.00 "
10.25 "
10'x11'
10.50 "
11.00 "
12.00 "
10'x15'
12'x14'
15'x15'
Grade 1 foot per 100 feet
Grade 1.5 feet per 100 feet
Grade 2.0 feet per 100 feet
Discharge in Cubic feet per Second.

# Diagram of Capacities of Sewers.